Habitat Particle Impact Monitoring System

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Johnson Space Center's (JSC's) Habitat Demonstration Unit (HDU) is a large-scale test bed designed for the testing and demonstration of technologies, processes, and operations that would be needed to support the future human exploration missions to the International Space Station, near-Earth asteroids, the moon, or Mars. The 2010 configuration of the HDU included a Pressurized Excursion Module (PEM) that measures approximately 6 meters (m) in diameter and 4 m in height), and an airlock (figure 1). NASA is planning to install a multilayer inflatable loft on top of PEM in late 2011. The construction of the HDU was completed at JSC in the summer of 2010. After a brief dry run at a JSC rock yard facility, the unit was shipped to the SP Mountain—approximately 40 miles north of Flagstaff, Arizona—and participated in a successful NASA Desert Research and Technology Studies (DRATS) campaign for 3 weeks in late August 2010.

Fig. 1. *The Habitat Demonstration Unit in front of the SP Mountain. The large module in the center is the Pressurized Excursion Module; the smaller structure to the left is the airlock.*

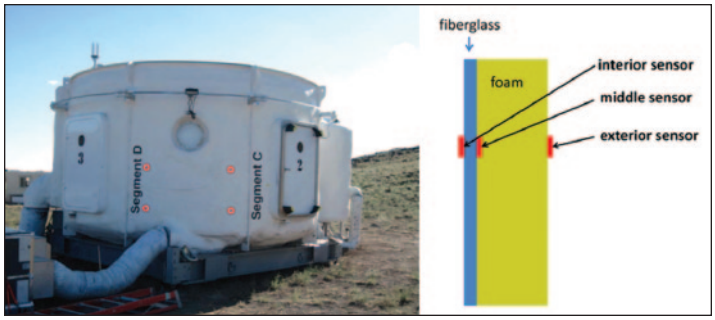

Fig. 2. *Left: the red circles indicate the locations of the sensors. Right: an illustration of the cross-section of the Pressurized Excursion Module wall structure.*

A key requirement to improve the safety of long-term habitat operations is the capability to monitor potentially damaging particle impacts on the structure. Sources of the impacting particles include orbital debris and micrometeoroids in the near-Earth environment, micrometeoroids and lunar secondary ejecta on the surface of the moon, and micrometeoroids in interplanetary space. NASA's Orbital Debris Program Office at JSC initiated an effort, with collaboration from the Naval Research Lab and Virginia Polytechnic Institute and State University, to develop the Habitat Particle Impact Monitoring System (HIMS) for the HDU in April 2009. Twelve space-qualified acoustic impact sensors were installed at four different locations and three layers on the wall of Section D of the PEM. The four locations are indicated by the red circles in the left portion of figure 2. The wall of the PEM consists of a fiberglass hard shell with a thickness of about 1 centimeter (cm) and an exterior layer of 10-cm-thick foam insulation. Sensors were attached both to the inside and outside of the PEM, and between the fiberglass shell and foam insulation (right portion of figure 2). The objective of the project in 2009-2010 was to demonstrate the HIMS capability of detecting particle impact location and the degree of impact penetration. The former is achieved by triangulation analysis using signals received by sensors at different locations. The latter is achieved by analyzing signal strength from sensors located at different layers.

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continued

The space-qualified HIMS sensors have been tested on different materials (aluminum plate, Kevlar®, multilayer insulation, etc.) subjected to hypervelocity impacts up to 7 kilometers per second (km/sec). For demonstration purposes during the DRATS campaign, however, hypervelocity impacts on the HDU were not possible. Instead, a 10-pump air rifle was used to simulate particle impacts. The degree of projectile penetration was controlled by varying the number of pumps of the air rifle. The speed of the projectile was also measured using a ballistic chronometer. It ranged from about 30 meters per second (m/sec) for one pump to 150 m/sec for 10 pumps. The transition from partial to full penetration through the foam insulation of the structure occurred around 130 m/sec.

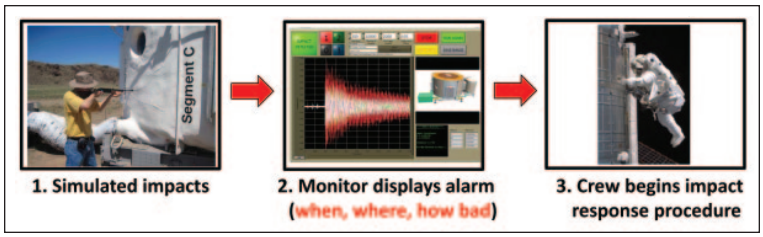

Fig. 3. *The goal of the Habitat Particle Impact Monitoring System project is to demonstrate the fully automated end-to-end capability, from simulated particle impacts to crew response based on processed impact information, during the 2011 Desert Research and Technology Studies campaign.*

HIMS team members conducted a successful impact test series during the 2010 DRATS campaign. The team collected a total of 113 air rifle shots and more than 20 hours of the HDU background acoustics data. Team members analyzed the data to optimize the HIMS parameters and developed a triangulation algorithm to identify each impact location. Key objectives for the project in 2010-2011 were to develop a three-dimensional graphical console to display impact time/location/penetration information in real time, to develop an impact response procedure for crew members in preparation for the integrated 2011 DRATS campaign, and to fully integrate the HIMS hardware and software into the existing infrastructure of the PEM. The aim for the 2011 DRATS campaign will be to test the end-to-end detection capability of the system (figure 3), and to demonstrate the potential applications of this low-cost, low-mass, low-power-consumption, easy-to-install system to other habitat structures, such as a multilayer inflatable, for future mission opportunities.